TOTAL EXCISION OF THE AORTIC ARCH FOR ANEURYSM

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AT THE PRESENT TIME the treatment of choice for aneurysms of the aorta is excision with preservation or restoration of aortic continuity. Certain factors, however, such as the location and nature of the lesion, may limit the successful application of this method of surgical therapy in thoracic aneurysms. In sacciform lesions, for example, as was indicated in our original report on this problem (1), resection is possible in virtually all cases, since this may be done by tangential excision and lateral aortorrhaphy without interruption of aortic flow. In fusiform aneurysms, on the other hand, which involve the entire circumference of the aorta, temporary occlusion of the aorta above and below the lesion is necessary in order to permit excision of the diseased segment and restoration of circulatory continuity by means of an aortic homograft or synthetic prosthesis (2). During the period of arrest of aortic circulation, serious ischemic damage may occur to tissues located distally, depending upon the duration and level of occlusion. Obviously, the more proximal the lesion and the higher the point of occlusion the greater is the likelihood of ischemic damage to vital organs and especially to the spinal cord which is highly vulnerable to such anoxic effects. Accordingly, this factor assumes particular importance in the resection of aneurysms located about the aortic arch. Our clinical and experimental observations (3, 7) have shown that it is possible to overcome this factor with the use of hypothermia. This therapy has been found to be an effective means of prolonging the safe period for temporary arrest of aortic circulation as high as the level of the left subclavian artery for a sufficient time, about 1 hour, for the performance of the procedure. With the aid of this measure virtually all aneurysms of the thoracic aorta located distal to the origin of the left common carotid artery may be considered resectable.

For fusiform aneurysms arising at a higher level the problem of resection becomes much more difficult and hazardous. Under these circumstances the necessity to clamp the ascending aorta proximal to the origin of the carotid arteries imposes serious cardiac effects in addition to the dangers of ischemic damage to the brain and spinal cord. For this reason excisional therapy of aneurysms located at this level has been limited almost entirely to tangential resection of sacciform lesions, which may be done without interruption of aortic circulation. Significantly the only cases of total resection of the aortic arch, reported by Schafer and Hardin and by Stranahan and associates, resulted in death of the patients in the operating room. Recently we had a case in which total arch resection was accomplished under hypothermia using temporary by-pass shunts in which the patient survived 6 days, and the purpose of this article is to consider briefly some of the technical aspects of the surgical problem.

CASE REPORT

E. L., a 49 year old white male, was admitted to Methodist Hospital on June 20, 1955, with pain in the left side of the precordium for 6 months and a nonproductive cough. The patient had contracted primary syphilis approximately 30 years previously but had had no specific treatment until 1939, at which time he received multiple injections of bismuth and arsenicals. Recently, because of the onset of the presenting

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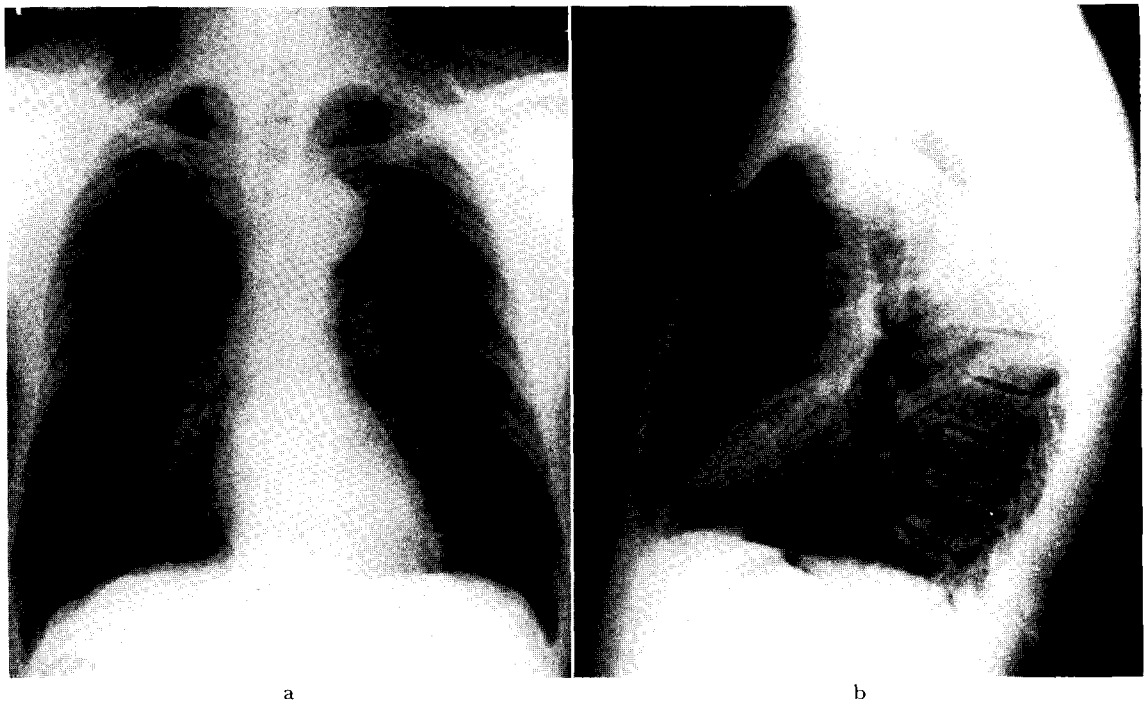

a b

FIG. 1. Roentgenograms of the chest showing a partially calcified fusiform aneurysm involving the entire aortic arch and a smaller aneurysm in the proximal portion of the descending thoracic aorta. a, Posteroanterior view; b, lateral view.

symptoms he received an intensive course of penicillin therapy without relief of symptoms.

Physical examination revealed increased retromanubrial dullness to percussion but there were no abnormal precordial pulsations. Blood pressure was 120/80 millimeters of mercury and the pulse was regular. The heart sounds were normal and there were no murmurs.

Routine laboratory studies were within normal limits and serologic test for syphilis was negative. Roentgenograms of the chest revealed a partially calcified fusiform aneurysm involving the entire aortic arch with a second smaller aneurysm originating just distal to the great vessels in the descending aorta (Fig. 1). The electrocardiogram revealed no abnormality.

At operation on June 24, 1955, general anesthesia was induced with intravenous pentothal® and the patient's rectal temperature was reduced to 93 degrees F. by surface cooling, using ice water and dilute alcohol supplemented with a single intravenous injection of 25 milligrams of chlorpromazine. With the patient in the supine and partly lateral position a left anterior thoracotomy was performed through the third intercostal space. After preliminary exploration of the chest had confirmed the presence of an aneurysm, the incision was extended across the sternum into the right third intercostal space, but the right pleural space was not entered. A vertical median sternotomy incision was then made extending into the suprasternal notch, providing adequate exposure of the aortic arch and major branches. The fibrofatty tissue in the anterior mediastinum was dissected away from the major vessels, and the pericardium overlying the ascending aorta was opened transversely. Because of the second aneurysm in the proximal portion of the descending aorta and the need for exposure of the lower portion of this segment of aorta, an intercostal incision was made in the left sixth space using the original skin incision and detaching the serratus anterior muscle from the underlying ribs. The ascending and descending thoracic aorta and the three major branches from the aortic arch were mobilized and encircled with tapes for traction.

The shunts which were made of compressed polyvinyl sponge (ivalon®) were sutured into place end-to-side using partial tangential occlusion clamps on the aorta and carotid arteries for this purpose (Fig. 2). When the ascending aorta was cross-clamped, the bypass which had an internal diameter of 14 millimeters carried the entire cardiac outflow and systolic blood pressure recorded in the legs fell only 10 millimeters of mercury from 90 to 80 millimeters of mercury. Shortly after clamping the ascending aorta the heart rhythm became irregular due to frequent extrasystoles and continued for a period of several minutes

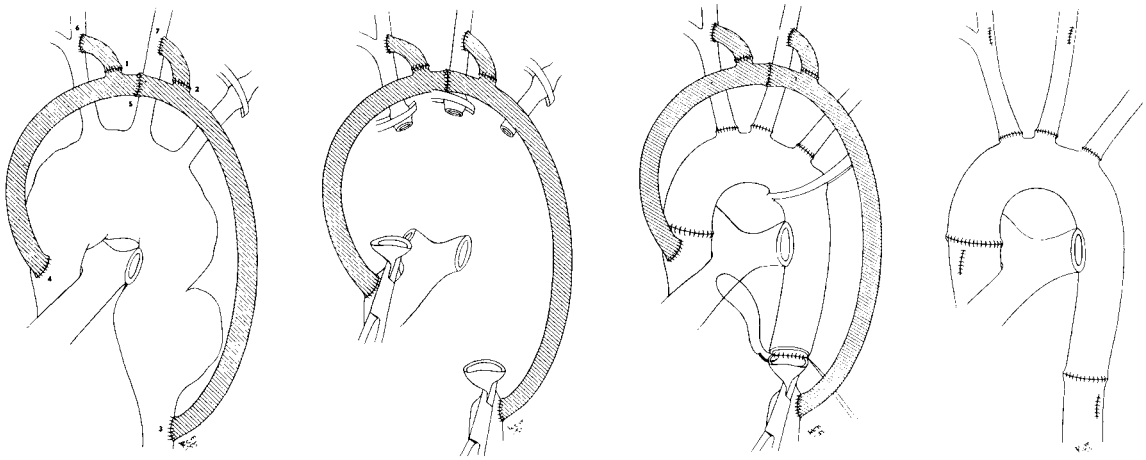

FIG. 2. FIG. 3. FIG. 4. FIG. 5.

FIG. 2. Drawing showing the technique of utilization of by-pass shunts to conduct blood from the ascending to the descending aorta and also into the innominate and left common carotid arteries during total arch excision and insertion of ivalon prosthesis.

FIG. 3. Drawing showing the functioning by-pass after excision of the entire aortic arch and proximal portion of descending thoracic aorta.

FIG. 4. Drawing showing anastomoses completed between the ascending aorta, innominate, left common carotid and left subclavian arteries and the compressed ivalon prosthesis permitting blood to circulate through these branches while the terminal anastomosis is performed.

FIG. 5. Drawing showing ivalon prosthesis in place after removal of the temporary by-pass.

after which regular sinus rhythm returned spontaneously. The left subclavian artery was occluded temporarily by a bulldog clamp. During this time the shunt provided circulation to the right subclavian and both carotid arteries, and strong pulsations were palpable in these vessels. The entire arch, as well as a portion of the descending aorta, was excised preserving the vagus and recurrent laryngeal and phrenic nerves (Fig. 3). The innominate, left carotid, and the left subclavian anastomoses were performed in that order using No. 0000 arterial silk. While completing the subclavian anastomosis the anesthetist reported that he was unable to feel a right carotid pulse. The proximal anastomosis to the ascending aorta was rapidly completed and the clamp was removed after 54 minutes of aortic occlusion (Fig. 4). Thus, blood was permitted to flow through the proximal portion of the prothesis and carotid pulses returned bilaterally. The right carotid pulse was absent for approximately 8 minutes. The distal aortic anastomosis was completed 21 minutes later and the aortic clamps were removed. The prosthesis functioned quite satisfactorily, and there was minimal blood loss after removal of the clamps. The shunt was then removed and the openings in the various vessels were oversewn with arterial silk sutures (Fig. 5). The dimensions of the prosthesis appeared to be ideal and there was no kinking or disproportion noted (Fig. 6). The incisions in the chest wall were then closed with chromic catgut and silk sutures, and catheters were placed into the left pleural space for underwater drainage. At the completion of the operation which lasted 8 hours, the patient's condition was stable and rectal temperature was 91 degrees F.

Rewarming was accomplished in a hydrotherapy tank at a water temperature of 112 degrees F., and the patient was removed from the tank 45 minutes later when his rectal temperature had risen to 99 degrees F. Respirations were normal and blood pressure was 120/80 millimeters of mercury. Pulses were palpable in all extremities and in the carotid arteries.

Although his general condition otherwise was very satisfactory, he did not regain consciousness. Twenty-four hours later he responded to painful stimuli and ophthalmic reflexes were normal. During the ensuing 5 days the lungs remained expanded and the prosthesis functioned well. Pulses were easily palpable and his blood pressure ranged around 130/80 millimeters of mercury. Although from time to time his state of consciousness seemed to improve somewhat, his condition began to deteriorate, and he died on the sixth day after operation.

Autopsy revealed that the prosthesis was intact and contained no thrombi. The brain showed no evidence of ischemic necrosis.

DISCUSSION

In general, the two major obstacles to successful resection of the entire aortic arch are

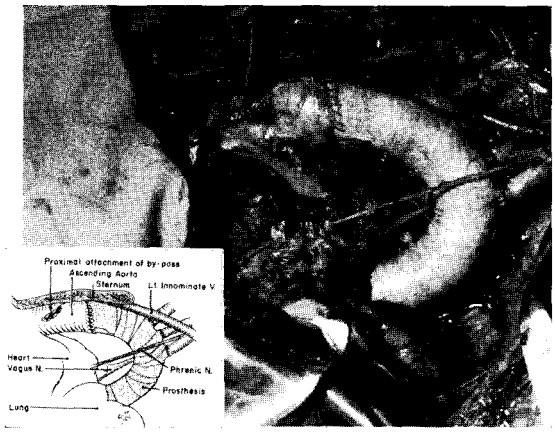

FIG. 6.

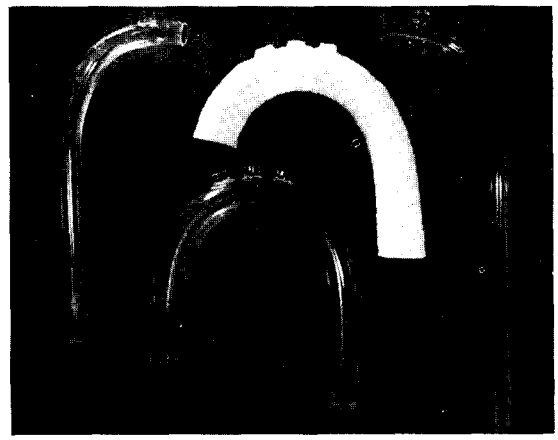

FIG. 7.

FIG. 6. Photograph made at thoracotomy showing ivalon prosthesis in place and the anastomoses to the ascending aorta and vessels of the arch. The drawing in the inset indicates the origin of the anastomoses to the great vessels of the arch and identifies other structures.

FIG. 7. Photograph showing the glass forms which were used to make the by-pass shunts as well as the prosthesis, and a compressed polyvinyl sponge prosthesis which has been removed from the form.

acute cardiac failure from ventricular strain and ischemic damage to the brain and spinal cord during temporary occlusion of the ascending aorta. Two methods of dealing with these problems are available, namely, the use of by-pass shunts to conduct blood around the diseased segment during its excision and replacement, and the use of hypothermia to reduce cardiac output and oxygen demand by the tissues.

Cross clamping the ascending aorta in animals leads to cardiac failure from left ventricular strain after relatively few heart beats. Izant, Hubay, and Holden have shown experimentally in dogs that a by-pass shunt measuring only 5 millimeters in diameter will preserve 80 per cent of the systemic blood flow and adequate pressure distal to the proximal occluding clamp to prevent ischemic damage to the spinal cord. Undoubtedly, the use of larger shunts would provide a more satisfactory flow distally and at the same time control hypertension in the segment of aorta between the left ventricle and the proximal clamp. For this reason, in our case, a relatively large shunt with an inside diameter of 14 millimeters was used and it is noteworthy that systolic blood pressure in the legs fell only 10 millimeters of mercury when the shunt was open and the ascending aorta was occluded. Hypertension in the proximal segment was probably minimized not only by the large caliber shunt but also by the hypothermic state which reduced cardiac output. Shortly after applying the clamp numerous extrasystoles were noted for several minutes but these disappeared and cardiac action remained stable for the remainder of the interval during insertion of the prosthesis.

With the exception of the central nervous system all organs lying distal to an occluding aortic clamp will tolerate periods of circulatory interruption for the average period of time, approximately 1 hour, required to accomplish the technical steps in aortic aneurysmectomy. Because of our previous experience (2, 3, 7) with hypothermia as an adjunct to surgical treatment of thoracic aneurysms, both hypothermia and by-pass shunts were employed to increase the margin of safety in the prevention of cardiac and neurologic damage.

Instead of using an aortic homograft in this case as has been our custom in segmental replacements of other regions of the

thoracic aorta, a compressed polyvinyl sponge (ivalon) prosthesis was employed because it provided a larger lumen tube to accommodate the somewhat dilated proximal and distal lumens of the aorta and also because the origins of the great vessels branching off the arch could be spaced sufficiently far apart to provide access for individual suturing. Accordingly, the prosthesis as well as the shunts were made of polyvinyl sponge, the use of which was first investigated in experimental animals by Grindlay and Waugh, in 1951. The glass forms which were used in producing the ivalon tubes were made by a professional glass blower using the measured 21 millimeter diameter of the aorta in the roentgenogram as a guide for making the arch prosthesis and the arbitrary 14 millimeter diameter for the shunt (Fig. 7). A method described by Mortenson was followed in which strips of wet ivalon were wrapped in layers on the glass tubes and compressed by an outer tight wrapping of ordinary gauze bandage. The glass forms and prostheses were autoclaved at 220 degrees F. for 20 minutes in a pan of distilled water following which the gauze wrapping and compressed sponge were removed from the forms. Such grafts are porous yet have a remarkably smooth inner lining. Moreover, the texture of these elastic tubes is favorable for suture, and bleeding around needle holes does not occur. On the basis of encouraging results of experimental use of such prostheses by Mortenson and by Shumway, Gliedman, and Lewis and of our own clinical experiences with 6 other cases of aortic grafts, this material can be recommended as a favorable arterial substitute for vessels of large caliber.

Death of the patient 6 days after operation was due to cerebral damage from temporary ischemia resulting from thrombosis of the right carotid shunt which occurred during the insertion of the ivalon prosthesis. Approximately 8 minutes elapsed from the time the thrombosis in the shunt was recognized until the clamp on the ascending aorta was released and carotid flow was re-established. Perhaps such technical complications of the procedure could be avoided by use of heparin either locally or systemically or preferably by siliconizing the inside of the tubes. Except for the accident which subsequently led to death of the patient the operation was performed without great difficulty. The fact that the patient survived the operation and lived for 6 days, during which time all peripheral pulses were readily palpable, testifies to the feasibility of total arch resection from a technical standpoint and justifies further attempts of this kind. Utilization of hypothermia in this case probably controlled the extent of cerebral injury which occurred preventing an earlier fatality and on this basis may be recommended as a useful adjunct to therapy in such cases.

SUMMARY

Excisional therapy for aneurysms of the aorta is now established as the method of choice. For fusiform aneurysms this procedure involves cross clamping the aorta above and below the diseased segment following which the lesion is excised and circulatory continuity is restored by means of an aortic homograft or prothesis. Temporary arrest of aortic circulation thus becomes the major hazard in the successful application of this procedure. This is particularly true for lesions lying in the aortic arch and requiring temporary occlusion of the ascending aorta. The two major obstacles under these circumstances are ischemic damage to the brain and spinal cord and cardiac failure from left ventricular strain. To overcome these problems two measures may be employed, namely, hypothermia and by-pass shunts.

A case is reported in which total excision of the aortic arch was performed followed by replacement with a prosthesis made of compressed polyvinyl sponge (ivalon). The patient survived 6 days during which period the prosthesis functioned well. The combined use of hypothermia and by-pass shunts in this particular case is considered to have contributed materially to the feasibility of the procedure.

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